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SHOCK ABSORBER AND ASSEMBLY FOR RECORDING SHOCK ABSORBER  
MOVEMENTS

BACKGROUND OF THE INVENTION

The present invention relates to a shock absorber with a piston rod accommodated in an outside housing so as to be slidable in its longitudinal direction. The invention further relates to an assembly for detecting shock absorber movements, in particular for a shock absorber of this type.

Shock absorbers usually comprising an outside housing and a piston rod arranged therein so as to be slidable in its longitudinal direction as well as associated assemblies for detecting shock absorber movements can be employed in general in mechanical engineering, plant construction or construction of apparatus, in particular in motor vehicle technology. Especially in modern concepts for electronic stability control in motor vehicles, yet also generally in connection with concepts for dynamic vehicle control, it is also possible to employ shock absorber control systems intended for the stabilization and/or improvement of the driving behavior, yet also for the use of related information in intelligent electronic braking and/or steering control systems.

Actors can be associated with individual shock absorbers in systems of this type, said actors rendering it possible to change the absorbing behavior of the respective shock absorber. A situation-responsive stabilization and/or improvement of the driving behavior of the respective motor vehicle can be brought about by a purposeful actuation of the actors. To achieve this aim, it is envisaged to purposefully actuate the respective

actors in response to demand and situation, in particular with respect to an evaluation of a currently detected actual condition compared to a nominal condition provided. To be able to appropriately take into account the actual condition of the respective shock absorber in a system of this type, that means especially the current positioning of its piston rod with respect to the outside housing which is typically fixed to the vehicle chassis, concepts are necessary to record corresponding position parameters and/or shock absorber movements.

An object of the invention is to devise a shock absorber of the above-mentioned type, which is especially appropriate for a robust and reliable detection of the position of its piston rod relative to the outside housing using simple means. Another objective is to devise an assembly for detecting shock absorber movements that is well suited for use of a related shock absorber.

#### SUMMARY OF THE INVENTION

As regards the shock absorber, this object is achieved by the present invention in that the piston rod or the outside housing is equipped with a magnetic encoder comprising a permanent-magnetic material with a modulated field line progression and/or modulated magnetic field strength extending in the longitudinal direction.

The invention is based on the consideration that a particularly robust and per se reliable concept for the pickup of measuring data should be provided especially when detecting a position parameter between the components of a shock absorber with respect to the comparatively great mechanical stresses that can possibly

be expected. For a high degree of reliability and fail-safety it is especially advisable to arrange a non-contact pick-up for measuring data. To render this possible, the pickup for measuring data is provided by resorting to magnetic auxiliary means, wherein the piston rod or the outside housing should be furnished with a suitable magnetic coding that is characteristic of a position parameter in its longitudinal direction.

The detection of the modulation of field line progression or field strength of the magnetic encoder is especially appropriate for determining position variations of the piston rod relative to the outside housing. However, in order to additionally provide a parameter for the absolute position of the piston rod with respect to the outside housing, which parameter lends itself to a particularly favorable use in further processing, the magnetic encoder in a particularly favorable embodiment is furnished with a separately readable position index which can be used as a reference or calibration basis for the evaluation of the position. The position index is advantageously provided with a coding that is detectable specifically by an associated sensor. E.g. a metallic position index may be provided for coding, which is selectively detectable by an associated metal detector as a sensor. Alternatively or additionally, the position index can also include a magnetization that differs characteristically from the otherwise provided magnetization of the encoder and can specifically be detected by an associated magnetic field sensor.

For applications in the determination of a position parameter for pedal drives, magnetic encoders with permanent-magnetic materials with a location-responsively modulated field line or field strength progression are disclosed in DE 100 10 042 A1. With regard to the possible embodiments of the encoders and the

sensors cooperating with the encoders, the disclosure of DE 100 10 042 A1 is included in full extent. Especially when viewed in the longitudinal direction of the piston rod, the magnetic encoder can include a large number of subsequent magnetization zones with alternating magnetization directions or also permanent-magnetic material with a magnetization that rises or declines continuously along the longitudinal direction.

A particularly simple type of construction can be reached by way of advantageously arranging the magnetic encoder at the piston rod. To allow a particularly simple assembly of the shock absorber and an associated pickup for measuring data, the magnetic encoder is favorably configured so as to be rotation-symmetrical about the longitudinal axis of the piston rod, so that a magnetization of even strength can be detected irrespective of the orientation of the magnetic encoder relative to the piston rod. This can be reached in an especially simple manner in that the magnetic encoder favorably has a generally tubular design and encloses the piston rod in a form-fit manner in an evaluation range. A particularly reliable guiding of the piston rod relative to the outside housing for stabilizing the shock absorber movements can be achieved because the piston rod with the encompassing magnetic encoder forms an outside surface preferably like a cylinder jacket that is largely free from grooves or projections in another favorable embodiment.

To avoid damage to the magnetic encoder due to mechanical influences, on the one hand, and allow a particularly compact mode of construction, on the other hand, a protective sheathing formed of a magnetically non-conductive material encompasses the magnetic encoder in another favorable embodiment.

To pick up a measured value that is characteristic of the positioning of the piston rod relative to the outside housing, the shock absorber is expediently equipped with sensors appropriate for sensing the magnetic coding of the piston rod or the outside housing. To this end, the shock absorber favorably comprises a number of magnetic field sensors fixed to the outside housing or the piston rod, to which associated sensor circuits can be added, as the case may be. The magnetic field sensors are favorably configured in such a fashion that they convert the magnetic field line progression fully or partly into output signals that can be further processed, and the magnetic field sensors used for displacement measurement can operate in particular according to the AMR principle, the GMR principle, or the Hall principle. AMR bridge combinations, e.g. known from WO 0151893, can preferably be used as magnetic probes.

For a compact and also reliable and robust construction, the magnetic field sensors are favorably arranged on a sensor carrier, which concentrically encloses the piston rod provided with the magnetic encoder. The sensor carrier is preferably arranged within the outside housing, as the case may be, jointly with an associated sensor signal processing unit, and, thus, within the shock absorber tube in total so that a particularly effective mechanical protection of the sensitive sensors is ensured in addition to the compact construction.

In another favorable embodiment, the magnetic field sensors are structurally grouped in a sensor subassembly comprising a feed line and/or a plug element for connecting a feed line.

Advantageously, the sensor subassembly is connected to the outside housing by way of a snap-type or catch-type engagement, in particular by way of an annular locking projection.

As regards the assembly for detecting shock absorber movements, in particular for a shock absorber of the above-mentioned type, the mentioned object is achieved in that a magnetic encoder that is arranged at a piston rod or at the outside housing of the shock absorber and comprises a permanent-magnetic material with a modulated field line progression and/or modulated magnetic field strength extending in the longitudinal direction cooperates with a number of magnetic field sensors fixed to the outside housing or the piston rod in order to generate output signals characteristic of a position parameter and adapted to be further processed.

In a particularly favorable embodiment, the shock absorber and the associated assembly for detecting shock absorber movements is employed in a system for shock absorber control. Said system comprises a controller unit which, on the inlet side, is connected to an assembly for detecting shock absorber movements of the mentioned type and which produces control commands for actors associated with the shock absorber in dependence on output signals produced by said assembly.

The assembly for detecting the shock absorber movement can then furnish output signals particularly characteristic of a local displacement of the piston rod relative to the outside housing and/or of the position of the piston rod relative to the outside housing. Said output signals can be used e.g. for determining speed parameters for characterizing the movement of the piston rod relative to the outside housing or for determining

acceleration parameters derived therefrom. It is e.g. possible in dependence on these parameters to purposefully influence the absorbing behavior of the shock absorber in response to the situation, and apertures for the hydraulic or damper oil are opened by suitably actuating valves or throttle flaps in dependence on the speed of the piston rod relative to the outside housing.

The advantages achieved by the invention involve in particular that the use of a magnetic encoder in a shock absorber with a comparatively simple construction allows a non-contact and, thus, especially robust sensing of measured values being characteristic of the articulation of the piston rod relative to the outside housing of the shock absorber.

An embodiment of the invention is explained in detail by way of the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings,

Figure 1 is a diagrammatic view of a device for absorber control.

Figure 2 is a representation of a simple shock absorber.

Figure 3 is a representation of an absorber with a modified piston rod.

Figure 4 is a schematic view of the assembly.



Figure 5 is a first embodiment of a sensor/encoder combination.

Figure 6 is a second embodiment of a sensor/encoder combination.

Figure 7 is a third embodiment of a sensor/encoder combination.

Figure 8 is a fourth embodiment of a sensor/encoder combination.

Like parts have been assigned like reference numerals in all Figures.

#### DETAILED DESCRIPTION OF THE DRAWINGS

Figure 1 shows a diagrammatic view of a system 1 for shock absorber control. Shock absorbers 2 are equipped with an assembly 4 for detecting the piston rod movement and comprise actuators 6 that allow changing the absorbing behavior. Sensors and actuators 6 cooperate with an electronic controller 8 to bring about a situation-responsive stabilization and/or improvement of the driving behavior. Further, the sensor's measured variables of the piston rod movements can also be sent to other data-processing vehicle systems, in particular braking and steering systems. A signal-linking unit 10 is provided for this purpose, advantageously in a configuration as a data bus (e.g. CAN).

Figure 2 shows the representation of a simple shock absorber 2 of Messrs. Krupp Bilstein. The piston rod 12 moves relative to the outside housing 14 during operation. The assembly of the invention is used to measure this linear movement. The transducer comprises a slidable element and a stator. Said slidable element includes a magnetic encoder. Fixed to the stator are sensor modules that can operate according to the AMR principle, the GMR

principle, or the Hall principle. The slidable element is guided in particular by means of a bearing connected to the stator.

Figure 3 shows the representation of a shock absorber 2 of this type with a modified piston rod 12. Piston rod 12 is concentrically tapered in an evaluation range 16 and encompassed by a tubular magnetic encoder 18. Encoder 18 is fixed to the piston rod 12. Encoder 18 in turn is encompassed by a protective sheathing 20 formed of a magnetically non-conductive material. The outside diameter of the encoder tube is reduced by the inside dimension of the magnetically non-conductive protecting tube or the protective sheathing 20 in relation to the non-tapered diameter of the piston rod 12. The outside diameter of the protecting tube is chosen such that the compound arrangement formed of piston rod 12, encoder 18 and protective sheathing 20 in the outside range is supplemented by the non-tapered piston rod 17 to provide an edgeless piston rod, the mechanical friction and sliding properties of which correspond to those properties of a conventional piston rod according to Figure 2.

Figure 4 shows the schematic representation of the overall assembly of the invention. A sensor carrier 22 concentrically embraces the piston rod 12 equipped with encoder 18. Sensor carrier 22 is coupled mechanically with the outside housing 14 of the shock absorber 2 in a fixed manner, as symbolized exemplarily herein by an annular locking projection 24. Inserted into the sensor carrier 22 are one or more magnetically sensitive magnetic field sensors 26 scanning the magnetic pole pattern of the encoder 18. Two magnetic field sensors 26 being cast or injection-molded in the sensor carrier 22 are provided in the embodiment. In an advantageous embodiment, the sensor modules comprise both the magnetic-field sensitive probes and the

associated electronic circuits for pre-processing the obtained encoder signals. A cable 28 leads the signals of the sensor modules from the sensor carrier 22 to the electronic controller 8 (Figure 1).

Figure 5 shows as a first embodiment a sensor/encoder combination with a rotation-symmetrical magnetization of an encoder tube 30 provided as encoder 18. The magnetization pattern is composed of equal, annular alternating north/south pole areas being scanned by a magnetic field sensor 26 via an air slot 32. The signals of the probe are conditioned by an electronic circuit arrangement 34 in such a fashion that, at its output, electric signals 36 with an increment information, i.e. an information about a displacement  $\Delta x$  when moving over a period of alternating magnetization directions, and an electric sign identification unit 38 are available, which can be transmitted to the electronic controller 8. Probe and circuit arrangement 34 together form the sensor module explained above. The incremental signals characterize the event of a performed piston rod displacement by the displacement increment  $\Delta x$  while the sign identification unit codes the direction of movement. The use of the encoder 18 involves the technical advantage that the sensor carrier 22 can be mounted with respect to the encoder 18 in a rotatorily non-aligned fashion, and subsequent rotatory relative movements between sensor carrier 22 and piston rod 12 will not influence the measurement. This sensor/encoder combination shall preferably be used for the dynamic absorber control on the basis of relative displacements, their speeds and accelerations.

Figure 6 shows as a second embodiment a sensor/encoder combination which is especially well suited also for determining

an absolute position of the piston rod 12 in relation to the outside housing 14. To this end, the encoder 18 has a position index 40, which can be read specifically and selectively in the way of a reference or calibration basis. In the embodiment of Figure 6, the actual magnetic coding of the encoder 18 encompasses said only in part in its circumferential direction. The position index 40, however, comprises a pole pair 42, 44 entirely enclosing the encoder 18 in its circumferential direction and associated with which are an invariable number of increments 46 of the unit interval  $\Delta y$ . Specifically associated with the position index 40 in this case is an appropriately positioned magnetic field sensor as sensor 50 which, due to its positioning, responds exclusively to the magnetization of the pole pair 42, 44. Due to the fixation of the encoder tube on the piston rod 12 and the knowledge of the location of the position index 40, the absolute local assignments are unambiguous, and when passing by the position index 40, calibration can be performed on the basis thereof. Additionally, there is redundancy with respect to the detection of the position in the area of the position index 40. Said redundancy can be used for safety concepts. This embodiment necessitates, however, a structural alignment of the piston rod with respect to the sensor carrier 22.

Figure 7 shows a third embodiment for a sensor/encoder combination, wherein the position index 40 was realized by a non-magnetic identification. Two different magnetic field sensors 26 and respectively associated circuit arrangements 34 are employed in this embodiment, being principally effective in the fashion described hereinabove. The position index 40 is designed herein by a magnetically inactive material zone, which is designed as a specifically associated sensor 50 in the example with a

capacitive probe or a probe corresponding to the principle of effect of a metal detector. The signals of the metal detector provided as sensor 50 are conditioned by means of a signal conditioning circuit 52 to form a characteristic signal 54. As described above, a calibration of the absolute position becomes automatically possible due to the fixed allocation of the zone to the position index 40. Like in the embodiment of Figure 5, the advantage of the non-aligned installation can also be used in Figure 7.

Figure 8 shows a fourth embodiment of the invention requiring an alignment between encoder 18 and magnetic field sensor 26. A sensor module of the type described above scans a tubular encoder 18, the magnetization of which is produced by a north/south pole pair having a neutral zone (field lines extend essentially in parallel to the surface of the cylinder) that winds in the way of a helical line along the encoder's longitudinal axis. The turning length of the helical line is chosen such that associated with each location of the encoder 1 in relation to the sensor module is a magnetic vector direction, which is unambiguously combined with the encoder position and detected by the sensor module. The advantage of this arrangement involves that it is possible to assign an unambiguous absolute value for the position relative to the outside tube of the shock absorber 2 for each possible position of the piston rod 12.

LIST OF REFERENCE NUMERALS:

1	system
2	shock absorber
4	assembly
6	actuators
8	controller
10	signal connection
12	piston rod
14	outside housing
16	evaluation range
18	encoder
20	protective sheathing
22	sensor carrier
24	locking projection
26	magnetic field sensors
28	cable
30	encoder tube
32	air slot
34	circuit arrangement
36	electric signals
38	sign
40	position index
42,44	pole pair
46	increments
50	sensor
52	signal conditioning circuit
54	characteristic signal